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The Ordovician succession from the western Iberian Ranges (NE Spain): a review with new data

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Key words: Iberian Ranges. Lithostratigraphy. Biostratigraphy. Ordovician. Spain.

Introduction

Calymenoid trilobites from the western Iberian Ranges (= Castilian branch of the Cordillera Ibérica) were already described as early as the middle of the eighteenth century, being the first Ordovician fossils reported from Spain. However, systematic studies on the Paleozoic rocks started a century later with discontinuous progress until the main contributions by Riba Arderiú (1959), Sacher (1966) and Villena (1976). Afterwards, studies on the Lower Paleozoic from the Castilian branch decreased drastically, because interest for Ordovician rocks had moved to the eastern or Aragonian branch, where the Paleozoic succession is more complete and displays very good outcrops. It resulted that the better known Ordovician sequence from the easternmost Iberian Range was generally considered as the type succession for the whole region, without detailed mentions of the western Ordovician occurrences (for instance see Liñán *et al.*, 1996). However, the previous studies mentioned above, together with the systematic mapping at 1:50,000 scale published by the Geological Survey of Spain (IGME) as well as some personal research by the authors, support the existence in the Castilian branch of pronounced stratigraphical and paleontological singularities with regard to the Aragonian branch.

The aim of our research is to establish a composite Ordovician succession based on several key areas of the Castilian branch (Figure 1), that includes stratigraphical refinements and a number of new fossil localities (Figure 2) which can be very useful for correlation and paleogeographical purposes.

Geological setting and stratigraphy

The Iberian Ranges (named as *Cordillera Ibérica* or *Sistema Ibérico* in Spanish language) is part of the European Alpine Belt which runs, with a general NW–SE orientation, to the northeast of the Hesperian Massif, the largest Variscan block formed by Precambrian and Paleozoic basement in the Iberian Peninsula (Figure 1). The Castilian branch is composed of large Alpine antiforms of Mesozoic rocks. Scattered occurrences of the Variscan basement with Paleozoic rocks ranging from the Lower

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Ordovician to the Carboniferous and with a general N–S trend are present in the core of the Sierra de Albarracín Antiform (to the NE) and the Serranía de Cuenca Antiform (to the SW).

The studied sections are representative of the largest Ordovician outcrops from these Variscan basement inliers, designated as «massifs» in the Spanish geological literature. They are the Aragoncillo and El Pobo–Sierra Menera massifs, included in the northern part of the Sierra de Albarracín Antiform (Figure 1). The Ordovician stratigraphy of the western Iberian Range has never been studied in detail, although a general stratigraphic scheme has been published by the authors listed above, which broadly improved pioneer works. These contributions also introduced a basic but rather confuse lithostratigraphical scheme, with different formational names and heterogeneous limits for similar units in each Paleozoic massif.

The oldest Ordovician formation is represented by more than 450 m of green to brown siltstones and shales, of unknown base, perhaps equivalent to the Santed Formation of the eastern Iberian Range of Late Tremadocian to Early Arenigian age. The overlying Armorican Quartzite is about 350 m thick and consists of a rather variable sequence that combines the typical thick–bedded quartzites with predominant shaly and silty intercalations placed at different levels. In SW Aragoncillo, Sierra Menera and Tremedal massifs, two main sedimentary episodes can be recognized, separated by probable unconformities of unknown amplitude. Both sequences are represented by massive quartzites, the lower one grading up into alternating shales and sandstones. The lower part of the succession is about 170 m thick and its top is a rhythmic sandy sequence with abundant

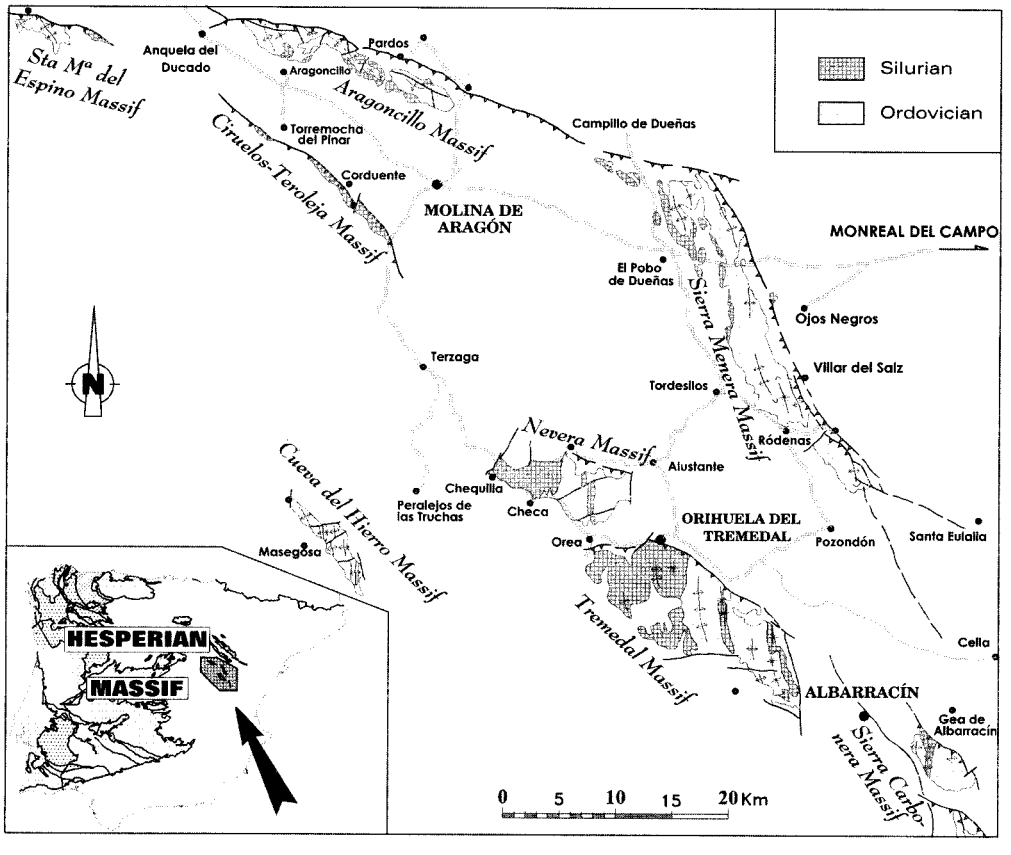

Figure 1. Geological sketch map of the main Paleozoic massifs of the Castilian Branch of the Iberian Ranges.

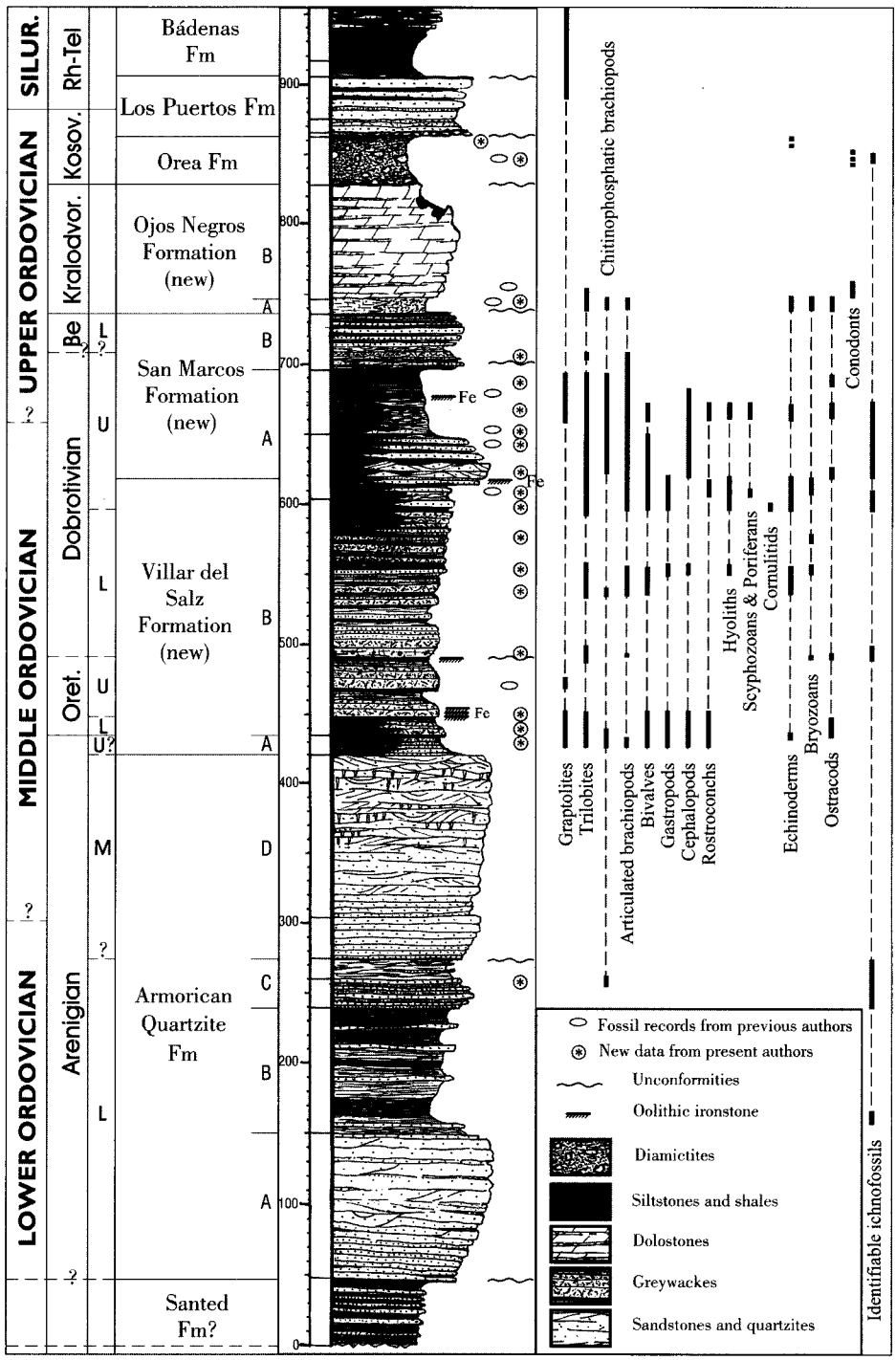

Figure 2. Composite Ordovician succession for western Iberian Ranges, mainly from Aragoncillo and Sierra Menera massifs; middle to upper Berounian rocks from the Nevera and Tremedal inliers ("Bronchales beds") are not represented. Abbreviations: SILUR, Silurian; Rh–Tel, Rhuddanian to Telychian; Kosov, Kosovian; Kralodvor, Kralodvorian; Be, Berounian; Oret, Oretanian; L, lower; M, middle; U, upper; A,B,C and D represent informal members.

ichnofossils and a lingulid shell bed. The upper part of the succession is formed by a thicker development of pure quartzites representing the typical Armorican Quartzite facies (over 130 m). In the NE sector of the Aragoncillo massif, as well as in the Aragonian branch, the formation is less homogeneous and comprises several quartzitic cycles ending with shales or fine sandstones, which probably represent lateral wedges from the main quartzite bodies.

The next unit, provisionally named Villar del Salz Formation, is roughly equivalent to the poorly defined «Llandeilo shales» or «La Venta formation» of earlier authors. The unit is formed by 150–350 m of microgreywacques and shales with some intercalations of sandstones of a highly variable development, even within the same Paleozoic massif. For instance, in the Sierra Menera outcrops, the formation is thicker towards the south, where it comprises up to five thinning–upwards sequences and a middle intercalation of sandstones. To the north, the formation is more monotonous, with thin sandy intercalations at the top that are replaced by rich noduliferous shales in the SW Aragoncillo Massif. Oolitic ironstones are commonly observed about 50–70 m above the base of the formation, and two other ironstone beds have been identified in the middle part of the Formation in the southern Sierra Menera massif.

Above the Villar del Salz Formation and below the Upper Ordovician limestones there are one or two sandstone units, that were erroneously differenciated in the Sierra Menera (Villena, 1976) as a basal member of the El Pobo limestones (Colmenarejos quartzites) or as an upper member laterally equivalent to the limestones (Tordesilos sandstones). Other local names for different outcrops are «Caradoc Alternation» (Aragoncillo) or Serretilla quartzites (Sierra Carbonera). The best stratigraphic development of these sandy units occurs in the Sierra Menera, where the new San Marcos Formation (40–165 m) is clearly outlined by two sandstone bodies with a middle shaly or silty intercalation. The unit illustrates two sedimentary fining–upwards sequences, differenciated as members. The lower one starts with pure quartzites and ends with sandy shales, and the upper one is composed of feldspatic sandstones that are more extensively developed at regional scale.

Above the quartzitic formation there are 0–15 m of green shales with volcaniclastic content and fossiliferous marls, overlain by a thick unit of dolomites (10–90 m), named here Ojos Negros Formation, because of the confuse range of the former Cabezo or El Pobo limestones. The top of the dolomites is either an erosional surface or consists of an open paleokarst with iron rich infilling (Ojos Negros iron mines). The Orea Formation overlies the unconformity, and is represented by 0–50 m of glaciomarine diamictites of the general type widespread all around the Mediterranean area, and with exotic siliceous or limestone clasts somewhere up to 30 cm. The uppermost Ordovician rocks belong to the lower part of the Los Puertos Formation, a quartzitic unit (1–50 m) that includes the Ordovician–Silurian boundary and that is succeeded by fossiliferous Telychian black shales.

The stratigraphic and sedimentological development of the Ordovician formations illustrates several transgressive megasequences starting with littoral sandy bodies, and grading up into open shelf pelitic sediments or even a carbonatic platform. However, the Orea Formation represents an exceptional glaciomarine sediment that only lacks in such areas (SW Aragoncillo–Sierra Menera rise) that were uplifted and emerged in coincidence with a global fall of the sea level in Kosovian (or Hirnantian) time, but that had been previously active subsident areas during the late Lower and the Middle Ordovician.

Paleontological data

The paleontological record from the Ordovician of the Castilian branch (except the middle and upper Berounian units, that are not represented in Figure 2) was scarcely known for more than two hundred years, being Riba Arderiú (1959), Sacher (1966) and Villena (1976) who

discovered most of the data known up to now. With the exception of some Upper Ordovician echinoderms, conodonts and ichnofossils (Gutiérrez–Marco *et al.*, 2002 and references therein), none of these Ordovician fossils has been the matter of detailed or even preliminary studies, as such studies concentrated on the coeval Ordovician faunas from the Aragonian branch of the Iberian Ranges. Taking into account the different stratigraphical development of some Middle and Upper Ordovician formations along the Iberian Ranges, correlation between the Ordovician successions from the two branches needed the finding of new key fossiliferous localities and precise biostratigraphical data.

Our preliminary and renewed research in the studied area induced the discovery of many new fossil localities as well as relocation and review of almost all of the localities mentioned by the former authors. We have examined about 32 different localities or fossiliferous horizons, which represents a significative improvement in the knowledge and correlation of the Ordovician succession of the Castilian branch (Figure 2). Our paleontological results can be summarized as follow, according with the north–Gondwanan regional chronostratigraphical scale (see Gutiérrez–Marco *et al.*, 2002, and references therein).

a) Arenigian fossils. The Armorican Quartzite does not yield any shelly faunas of stratigraphical value, but the age of this ubiquitous formation is well known elsewhere. The heterolithic facies from the middle part of the unit includes a lingulid shell bed up to 15 cm thick with *Linguloholus brimonti* (Rouault) and *Lingulepis*. A rich ichnofossil assemblage with *Cruziana rugosa* d'Orbigny, *C. furcifera* d'Orbigny, *C. lefevbrei* d'Orbigny, *Dimorphichnus, Lingulichnites, Teichichnus, Daedalus halli* (Rouault), *Monocraterion* and *Skolithos* among others, was studied in the northern Sierra Menera and Aragoncillo massifs.

Shelly faunas of probable Upper Arenigian age occur at the base of the Villar del Salz Formation in the western part of the Aragoncillo Massif: this assemblage, up to now unknown from Spain, shows some resemblance to older Arenigian faunas of the Montagne Noire (SE France) and Moroccan Anti–Atlas. The assemblage is composed of trilobites as *Basilicus* (*Basiliella*?) cf. *destombesi* Vidal, *Asaphellus* cf. *cianus* (Verneuil and Barrande), *Megistaspis*, nileids, *Salterocoryphe sampelayoi* Hammann, *Neseuretus* sp. nov., illaenoids; bivalves as *Ekaterodonta hesperica* Babin and Gutiérrez–Marco, *Goniophora (Cosmogoniophora)*, cf. *Ctenodonta escosurae* (Sharpe) and some long–ranging species [*Redonia deshayesi* Rouault, *Praenucula costae* (Sharpe), *Hemiprionodonta lusitanica* (Sharpe)]; gastropods (*Sinuites*), transversely annulated orthoconic nautiloids, rostroconchs (*Ribeiria pholadiformis* Sharpe), brachiopods (*Ranorthis*) and graptolites [*D. (Expansograptus)*].

b) Oretanian fossils. Lower Oretanian beds are documented for the first time in the Iberian Range. Abundant graptolites as *Didymograptus artus* Elles and Wood are found in profusion in shales and siltstones, sometime accompanied by rare trilobites (*Platycoryphe, Asaphellus*). Fossiliferous nodules from underlying oolitic ironstones yielded trilobites (*Pradoella pradoi* Hammann, *Neseuretus* sp. nov. aff. *attenuatus* (Gigout), *Asaphellus*), ostracods [*Gracquina hispanica* (Born)], cephalopods (*Cameroceras*), gastropods (*Sinuites,?Tropidodiscus*) and some long–ranging species of bivalves and rostroconchs [*Hemiprionodonta lusitanica, Cardiolaria beirensis* (Sharpe), *Ribeiria pholadiformis* Sharpe]. Upper Oretanian beds are largely unfossiliferous, except in the Sierra Carbonera massif where *Didymograptus murchisoni* (Beck) was recorded. The upper limit of the upper Oretanian is placed tentatively immediately below the first record of typical Dobrotivian fossils.

c) Dobrotivian fossils. Rocks assigned to this regional stage are by far the most fossiliferous of the studied Ordovician sequence and correspond to a large number of fossil localities discovered in the different inliers. Lower Dobrotivian beds contain *Neseuretus tristani* (Brongniart), *Colpocoryphe rouaulti* Henry, *Eohomalonotus sdzuyi* Hammann and Henry (only found in sandstones), *Placoparia (Coplacoparia) tourneminei* Rouault, *Panderia beaumonti* (Rouault), *Ectillaenus, Morgatia hupei* (Nion and Henry) and *Eodalmanitina*, among others. There are also ostracods (*Quadrijugator*,

Tetradellidae), echinoderms (*Calix rouaulti* Chauvel, *Anatifopsis ancora* Domínguez and Gutiérrez–Marco, ?*Balanocystis*, pelmatozoan columnals), brachiopods [*Heterorthina morgatensis* Mélou, *Apollonorthis bussacensis* Mélou, *Eorhipidomella musculosa* (Mélou), *Aegiromena mariana* Drot], hyoliths (*Gompholithes beirensis* (Sharpe), *Elegantilites*), gastropods [*Sinuites, Tropidodiscus pusillus* (Barrande), *Ptychonema* cf. *bussacensis* (Sharpe)], cephalopods, bivalves (*Praenucula costae, Redonia deshayesi, Cardiolaria beirensis*), rostroconchs (*Ribeiria pholadiformis*) and ichnofossils (*Arachnostega gastrochaenae* Bertling, *Tomaculum problematicum* Groom, *Syncoprulus, Chondrites, Planolites, Tisoa*).

The upper Dobrotivian can be identified by the abundance of *Placoparia (C.) borni* Hammann and the incoming in slightly higher beds of the graptolite *Oepikograptus bekkeri* (Öpik), a Scandinavian species indicative of the *Nemagraptus gracilis* Biozone. A large part of the molluscs and brachiopods mentioned for the lower Dobrotivian are also recorded in the upper Dobrotivian, as for instance *Aegiromena, Eorhipidomella, Tropidodiscus, Ptychonema, Praenucula*, etc. However, a special lithofacies of shales with fossiliferous nodules occurs in the Aragoncillo Massif, passing laterally to the lower member of the San Marcos Formation: it has yielded a rich assemblage of trilobites with *P. (C.) borni, Eccoptochile, C. rouaulti, N. tristani, N. henkei* Hammann, *Prionocheilus mendax* (Vanek), *Eodalmanitina destombesi* (Henry), *Phacopidina micheli* (Tromelin), *P. beaumonti, Nobiliasaphus* and *Selenopeltis*. The nodules bear abundant schizocranid and lingulid brachiopods (*Schizocrania salopiensis* Williams, ?*Monobolina*) representative of offshore environments, poriferans, cornulitids and rare bivalves and gastropods (minute *Praeleda, Ctenodonta escosurae, Archinacella*). Shallower facies in the Sierra Menera, Nevera and Sierra Carbonera massifs also contain *Heterorthina kerfornei* Mélou, *Apollonorthis bussacensis, E. musculosa* (brachiopods); *Myoplusia bilunata perdentata* (Barrande) and *Modiolopsis* (bivalves); *Technophorus sharpei* (Barrande) (rostroconch), *Lardeuxella* (ostracod), *Calix rouaulti* (diploporid echinoderm) and bryozoans. Finally, the basal sandstones of the upper member of the San Marcos Formation yielded abundant brachiopods as *Tafilaltia valpyana* (Davidson) and *Heterorthis*, together with calymenoid (*Eohomalonotus*) and phacopoid trilobites.

d) Berounian fossils. Although the lower Berounian would be probably represented in the highest beds of the San Marcos Formation, the basal unconformity of the Ojos Negros Formation (Kralodvorian) caps by erosion or non–deposition younger Berounian beds in the northern inliers. However, in the Tremedal, Nevera and Collado de la Plata massifs, fossiliferous middle and upper Berounian beds are represented above the San Marcos Formation and below the Kralodvorian limestones and marls. The sequence consists in a thick unit (at least 150–200 m) of shales and shale–sandstone alternations ending with massive quartzites («Bronchales beds»). Middle Berounian fossils identified in the Collado de la Plata massif (south of Sierra Carbonera) correspond to characteristic brachiopods as *Svobodaina armoricana* Babin and Mélou, as well as trilobites (*Zetillaenus ibericus* Hammann, *Prionocheilus* cf. *almelai* Hammann), echinoderms (rombiferan cystoids, *Calix* cf. *gutierrezi* Chauvel and Meléndez and *Mespilocystites lemenni* Gutiérrez–Marco), gastropods [*Holopea? antiquata* (Barrande)], benthic graptolites (*Reticulograptus*) and trepostomate and cryptostomate bryozoans. Upper Berounian assemblages from the Tremedal massif yielded the trilobites *Deanaspis* cf. *malladai* (Oehlert), *Zetillaenus ibericus* and *Dalmanitina*, together with graptolites (Diplograptids and *Reticulograptus*), bryozoans and brachiopods.

e) Kralodvorian fossils. The basal marls and the lower part of the limestone member are fossiliferous in the Aragoncillo, Nevera and Tremedal massifs, yielding pelmatozoan columnals, trilobites (*Ovalocephalus, Cekovia*), brachiopods (orthids and *Orbiculoidea*), bryozoans (*Chasmatoporella* and other Trepostomate and Cryptostomte forms), Cystoids (Caryocystitida?, Hemicosmitida), ostracods and conodonts (*Amorphognathus, Scabbardella*, «*Eocarniodus*», *Panderodus, Icriodella* and *Sagittodontina*), the last assemblage being indicative of the *Amorphognathus ordovicicus* Biozone.

f) Kosovian fossils. In the Tremedal massif, the Orea Formation includes siltstone beds with ichnofossils (*Allocotichnus palmatus* Aceñolaza and Gutiérrez–Marco, *Arenicolites*, Pascichnia). Reworked limestone pebbles and isolated echinoderm ossicles derived from the Ojos Negros Formation were recognized in the Sierra Carbonera massif (*Cyclocharax, Aonodiscus*, rhombiferans). In the Nevera Massif, other dropstones coming from Kralodvorian limestones have yielded some conodonts as *Amorphognathus ordovicicus* (Branson and Mehl), *Sagittodontina robusta* Knüpfer and *Scabbardella altipes* (Henningsmoen).

Biostratigraphical summary

Upper Arenigian and lower Oretanian fossils are documented for the first time from the Iberian Ranges, in the lowermost part of the Villar del Salz Formation. In the Aragonian branch, coeval sediments are unknown and the upper Oretanian shales and ironstones directly overlie the Armorican Quartzite. Paleontological data show that the main part of the Villar del Salz Formation can be referred to the Dobrotivian, and that the upper part of this formation in the Aragoncillo massif is also a lateral equivalent of the lower Member of the San Marcos Formation of the Sierra Menera Massif. Basal fossiliferous beds occurring in the widespread sandstones («Colmenarejos quartzites») that constitute the upper member of the San Marcos Formation, are still of upper Dobrotivian age, but higher strata could already be lower Berounian. Middle and upper Berounian beds are unknown in the northern part of the Castilian branch, where the Ojos Negros Formation unconformably overlies older rocks. However, a thick sequence of sandstones and shales of these ages occur in the Nevera, Tremedal and Collado de la Plata massifs. The Ojos Negros Formation is of Kralodvorian age, being laterally developed as limestones in the shelf or uplifted areas, and in marly facies in more offshore or deeper settings. Kosovian sediments bear only ichnofossils and contain also reworked fossils in glaciomarine dropstones. The Ordovician–Silurian boundary lies within the Los Puertos Formation, according with basal Silurian graptolite data and correlation with other areas of the Hesperian Massif (for references see Gutiérrez–Marco *et al.*, 2002).

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